CLAIMS

1. A rate responsive pacing system having a pacemaker device and a lead system interconnecting said device and a patient's heart, said device having a pulse generator for generating pacing pulses, sensing means for sensing cardiac signals connected from said heart by said lead system, sensor means for determining from received cardiac signals a sensor pacing rate, and rate control means for controlling said pulse generator to deliver pacing pulses at said sensor rate, said sensor means comprising

algorithm means for calculating a measure of the T wave portion of a received intrinsic cardiac signal;

comparing means for comparing said measure with a predetermined criterion to detect the occurrence of the T wave portion of said signal;

data means for determining and storing intrinsic QT interval data and heart rate data for each received intrinsic signal for which a T wave has been detected; and

reference means for setting a QT reference curve as a function of said stored intrinsic QT interval and rate data.

2. The system as described in claim 1, wherein said sensor means comprises high rate limit means for setting a maximum sensor rate, and wherein said algorithm means, said comparing means and said data means are operative at rates above said maximum sensor rate.

3. The system as described in claim 1, wherein said algorithm means comprises integration means for integrating said T wave portion, and said comparing means comprises programmable storage means for storing a threshold integral value that represents a valid T wave sense.

4. The system as described in claim 3, comprising Vpace means for determining when a ventricular pace has been delivered, second QT data means for determining evoked QT interval data and heart rate data, and compensating means for compensating said evoked QT interval data to account for the difference between intrinsic and invoked QT intervals.

5. The system as described in claim 4, wherein said second QT data means comprises slope means for detecting the occurrence of maximum T wave slope and for determining the time of said slope as the time of T wave occurrence.

6. The system as described in claim 1, comprising second algorithm means for determining and storing values of evoked QT interval for evoked cardiac signals, and wherein said rate control means comprises calculating means for calculating sensor rate following a ventricular event as a function of said QT reference curve and the QT interval.

7. The system as described in claim 6, wherein said second algorithm means comprises compensation means for compensating each determined value of evoked QT interval to correspond to an intrinsic QT interval at the same rate.

8. The system as described in claim 7, wherein said compensation means comprises ms means for adjusting each determined value of evoked QT interval by a predetermined ms value, thereby compensating for the difference in measurements of intrinsic and evoked QT intervals.

9. The system as described in claim 6, wherein said data means has storage for storing data for a predetermined time, and wherein said reference means comprises means for calculating said QT reference curve when said data has been stored for said predetermined time.

10. The system as described in claim 9, wherein said reference means comprises time means for calculating said reference curve when data has been stored for a time period in the range of one day to one month.

11. The system as described in claim 1, comprising ectopic means for determining when a sensed cardiac signal represents an ectopic beat, and for setting said sensor rate as unknown for any such ectopic beat.

12. The system as described in claim 11, wherein said ectopic means comprises DSP circuitry for analyzing the shape of a sensed cardiac signal.

13. A rate responsive pacing system having a pacemaker device and a lead system interconnecting said device and a patient's heart, said device having a pulse generator for generating pacing pulses, sensing means for sensing cardiac signals connected from said heart by said lead system, sensor means for determining from received cardiac signals a sensor pacing rate, and rate control means for controlling said pulse generator to deliver pacing pulses at said sensor rate, said sensor means comprising:

rate means for determining values of the patient's heart rate each cardiac cycle;

intrinsic means for obtaining QT intervals of intrinsic ventricular signals;

stim means for obtaining evoked QT intervals of stimulated ventricular signals;

compensating means for compensating said evoked QT intervals to obtain compensated QT intervals that correspond to intrinsic QT intervals;

reference means for constructing and storing a QT reference curve from said intrinsic QT intervals and said rate values; and

calculating means for determining said sensor pacing rate from each respective QT and compensated QT interval.

14. The system as described in claim 13, wherein said compensating means comprises a stored constant value and an adjustment algorithm for adjusting the evoked QT by said stored value.

15. The system as described in claim 13, comprising differential means for storing data representing the difference between intrinsic QT and evoked QT as a function of rate.

16. The system as described in claim 13, wherein said intrinsic means comprises

algorithm means for calculating a measure of the T wave portion of a received intrinsic signal;

comparing means for comparing said measure with a predetermined criterion to detect the occurrence of an intrinsic T wave; and

timing means for determining the QT time of an intrinsic signal having a detected T wave.

17. The system as described in claim 16, wherein said algorithm means comprises integrating means for integrating said signal within a predetermined time following the R portion of said signal.

18. The system as described in claim 17, wherein said comparing means comprises threshold means for comparing said integration with a predetermined threshold value.

19. The system as described in claim 17, wherein said timing means comprises means for obtaining the slope of said T wave portion and for determining the peak value of said slope.

20. A method of obtaining intrinsic QT data for a QT sensor used in a cardiac pacing device that is implanted in a patient, comprising:

receiving patient QRST signals;

determining when an intrinsic R wave has occurred;

initiating a T wave measuring operation after the occurrence of a said R wave;

carrying out said measuring in accordance with a predetermined algorithm and comparing the resultant measure with at least one predetermined criterion to detect the occurrence of a T wave; and

determining the time of a predetermined characteristic of a said received signal that is detected as a T wave, and obtaining a value of QT as the time from said intrinsic R wave to said characteristic time.

21. The method as described in claim 20, wherein said measuring comprises integrating the received signal.

22. The method as described in claim 21, wherein said initiating is started a predetermined time interval following an intrinsic R wave.

23. The method as described in claim 22, comprising storing a threshold value of the integrated signal that represents a T wave, and wherein said comparing step comprises continually comparing said integrated signal as it is being obtained to said stored threshold value.

24. The method as described in claim 23, further comprising storing each value of QT with corresponding rate data.

25. The method as described in claim 24, comprising storing said QT and rate data for at least a predetermined time, and calculating a QT reference curve from said stored data following said time.

26. The method as described in claim 20, comprising the slope of said signal, determining the time of the maximum of said slope, and determining the value of QT as the time from the occurrence of the R wave to the time of said slope maximum.

27. A method of controlling the pacing rate of a pacing system implanted in a patient, comprising:

sensing intrinsic patient ventricular signals;

determining from each said sensed signal the time of the R wave and calculating and storing the rate of each last cardiac cycle;

analyzing each said sensed signal within a predetermined time window following the R wave time to determine at least one measure of said signal;

comparing said measure to at least one criterion and detecting the occurrence of a T wave as a function of said comparing;

for a said detected T wave, determining the time between said R wave and said T wave and storing said time as a value of intrinsic QT;

storing a QT reference curve that provides reference values of QT as a function of rate;

comparing each determined value of QT to said reference curve and determining therefrom an indicated pacing rate; and

controlling the rate of pacing as a function of said indicated pacing rate.

28. The method as described in claim 27, comprising storing values of intrinsic QT and rate corresponding to each detected T wave, and periodically recalculating said QT reference curve as a function of said stored values.

29. The method as described in claim 28, comprising determining when a sensed ventricular signal represents an ectopic beat, and inhibiting determination and storing of a QT value for any such ectopic beat.

30. The method as described in claim 27, comprising determining the occurrence of a predetermined property of a said detected T wave, and storing the time between said R wave and said occurrence as the value of QT.

31. The method as described in claim 30, comprising obtaining the slope of said sensed signal following the R wave, and determining the time of the maximum of said slope.

32. The method as described in claim 31, comprising initiating a time window a predetermined number of ms following the time of said R wave.

33. The method as described in claim 32, comprising integrating said sensed signal at the start of said time window.

34. The method as described in claim 33, comprising storing a threshold integration value, and continuing said integrating until the integral reaches said threshold or said time window times out.

35. The method as described in claim 34, comprising detecting a T wave when said integral reaches said threshold.

36. The method as described in claim 27, comprising determining when there has been a delivered ventricular pace, determining a value of evoked QT for the evoked QRST following a delivered ventricular pace, and compensating said evoked QT to correct for the longer time of an evoked QT compared to an intrinsic QT.

37. The method as described in claim 36, comprising storing values of rate and compensated QT following a delivered pace.

38. The method as described in claim 36, comprising periodically recalculating said QT reference curve as a function of stored values of intrinsic and compensated QT.

39. The method as described in claim 38, comprising storing values of QT and corresponding values of rate for ventricular events across the patient's rate spectrum, and downloading said QT and rate data to an external site for analysis.

40. The method as described in claim 27, comprising determining values of evoked QT for evoked ventricular events, compensating said values of evoked QT to substantially equate them to intrinsic values, and determining indicated pacing rate by comparing any determined value of QT to said QT reference curve.

41. The method as described in claim 40, comprising storing values of intrinsic and evoked QT and corresponding rate values, and periodically recalculating said QT reference curve as a function of said stored values.

42. An implantable pacing system for pacing a patient, said system having a pacing generator that generates pacing pulses at a controllable pacing rate and a rate control subsystem for controlling pacing rate, said subsystem comprising:

signal circuitry for receiving and processing intrinsic patient ventricular signals;

R wave means for detecting the occurrence of an R wave;

T wave means for determining the occurrence of a T wave, said T wave means comprising measure means for obtaining a measure of each said intrinsic signal over a period of time following a detected R wave;

QT means for determining the intrinsic QT interval of an intrinsic signal having a detected R wave and a detected T wave; and

rate control means for controlling pacing rate as a function of determined QT intervals.

43. The system as described in claim 42, wherein said T wave means further comprises storage that stores predetermined T wave criteria, and comparing means for comparing said measure with said criteria.

44. The system as described in claim 43, wherein said measure means comprises window means for initiating a window at a predetermined time following a detected R wave, and integrating means for integrating each said received intrinsic signal starting at the initiation of a said window.

45. The system as described in claim 44, comprising DSP circuitry for providing the slope of said intrinsic signal following a detected T wave, and peak means for identifying the maximum value of said slope as the time of a T wave.

46. The system as described in claim 45, comprising storage means for storing values of intrinsic QT and rate for each detected T wave.

47. The system as described in claim 46, comprising reference means for calculating a QT reference curve as a function of said stored values.

48. The system as described in claim 47, comprising DSP means for determining when a sensed ventricular signal represents an ectopic beat, and inhibiting means for inhibiting determining of a QT value for any such ectopic beat.

49. The system as described in claim 42, further comprising means for determining the QT interval of evoked ventricular beats and for storing data representative of said evoked QT intervals.

50. The system as described in claim 49, comprising means for compensating values of QT interval of evoked beats to substantially equate such values with intrinsic values of QT interval.

51. The system as described in claim 50, comprising storage means for storing determined intrinsic and evoked QT intervals, and reference means for constructing a QT reference curve from said stored values.